

U.S. Department of Energy The ARM Unmanned Aerospace Vehicle Program



The Proteus aircraft from Scaled Composites has carried the ARM-UAV payload in major science flight campaigns.

The U.S. Department of Energy's (DOE's) Atmospheric Radiation Measurement Unmanned Aerospace Vehicle (ARM-UAV) Program uses UAV and occupied aircraft to make key climate measurements that cannot be made by other means.

UAVs are remotely controlled aircraft, which were originally developed for defense surveillance and are now being used in a variety of applications. Because they are unmanned, they can fly higher and longer than manned aircraft. Their long endurance at high altitudes is important in studying how clouds interact with the earth's solar and thermal radiation to heat or cool the earth. ARM-UAV is developing UAV-compatible sensor payloads and measurement techniques and using those payloads and capabilities in UAV and piloted aircraft science flights to acquire important climate-related data.

A UAV or piloted aircraft instrumented with the ARM-UAV payload can provide measurements of the scattered solar and emitted thermal radiation at multiple levels in the atmosphere and in situ observations of the numbers of different sizes and shapes of ice crystals at these altitudes. This combination of observations can give a better determination of interactions of clouds with solar/thermal energy, a better quantification of the atmosphere's rate of heat absorption, and better calibration data for satellite-based measurements. When combined with ground-based measurements, these UAV-based measurements reduce the uncertainty of predictions about greenhouse warming, a key element in global climate research.

Capabilities

ARM-UAV is a multi-laboratory program. Sandia National Laboratories (SNL) is responsible for overall technical direction of the program. Over the life of the program, other key team members have contributed the following capabilities:

- National Aeronautics and Space Administration (NASA) Ames, Scripps Institute of Oceanography, and Colorado State University provided radiometric instruments.
- NASA Goddard provided a microwave radiometer.
- NASA Langley conducted satellite data comparisons.
- Los Alamos National Laboratory (LANL) provided a scientific instrument calibration capability.
- Brookhaven National Laboratory (BNL) provided meteorological instruments.
- Pacific Northwest National Laboratory (PNNL) provided data management.
- The University of Maryland, Florida State University, and the University of Illinois provided the mission scientists for UAV missions.
- Lawrence Livermore National Laboratory (LLNL), SNL, and LANL are developing highly accurate climate instrumentation designed for UAVs.
- Droplet Measurements Technology (DMT), Gerber Scientific, SkyTech Research, and the National Center for Atmospheric Research (NCAR) provided probes for in situ measurements of ice crystals.

Instruments

The ARM-UAV team has developed compact, highly accurate instrumentation for the ARM-UAV Program. These instruments include:

- A wide field-of-view, imaging cloud radiometer for retrieving cloud reflectivity, for resolving the phase of cloud droplets (ice or water) and their effective size, and for calibrating various satellite measurements (SNL).
- A fully eye-safe lidar for detecting and profiling thin cirrus clouds, which are difficult to measure by other techniques, but which may contribute significantly to the earth's radiation balance (LLNL).
- Net flux radiometer for accurately measuring the difference between the up- and downwelling radiation (LANL).

Additional instrumentation will be developed as needs are identified.

Accomplishments

The ARM-UAV Program is being accomplished in three phases:

- The first phase, to establish the utility of UAVs as an atmospheric measurement platform, has been completed. An existing UAV (the General Atomics Gnat 750) and modified versions of radiometers, which were originally developed for manned aircraft, were used in eight highly successful flights at the DOE ARM research site in Oklahoma. The instrumentation measured atmospheric heating under a variety of clear-sky atmospheric conditions up to an altitude of 7 km. Preliminary analyses show excellent agreement between the resulting measurements and computational models.
- The second interim measurement phase demonstrated important system growth capabilities through sustained operations (endurance/high altitude). This phase used existing and near-term instruments on the General Atomics "Altus" UAV, which flies at altitudes of up to 20 km for more than 2 hours. Payloads for these flights consisted of instruments tailored for UAV application to study radiation-cloud interactions, especially the recently identified enhanced cloud absorption. The highlights of this phase include an unprecedented 26-plus-hour science flight and an altitude record of 57,000 feet, both accomplished by the "Altus" UAV.
- The third phase demonstrates a transition to more routine observations with ARM-UAV playing a critical role in collecting valuable datasets for the

scientific community in field measurement campaigns. Measurements are currently being made using the one-of-a-kind piloted Proteus aircraft, available from Scaled Composites, that can fly over 50,000 feet for more than 12 hours at a time. The current ARM-UAV payload includes both in situ and active and passive remote sensing measurements of clouds and radiation. The payload collecting these measurements has been flown over the Oklahoma research site and the North Slope of Alaska and will be flown over the Tropical Western Pacific site at Darwin, Australia. It is critical to acquire such long-term observations at remote locations, such as Australia and Alaska. It is known that significant climatic changes are occurring in the Arctic and that interactions between clouds, the atmosphere, and ocean are more complex there than in other regions, yet these interactions are not well understood. In the tropics, water vapor and cloud-radiative interactions in the upper troposphere above the Pacific warm pool play such a critical role in future climate change scenarios that the region is sometimes referred to as "nature's greenhouse laboratory." Thus, these ARM-UAV observations are providing unique data that will help represent cloud-radiative effects in the models that will be used by policy makers to determine safe levels of greenhouse gases for the earth's system.

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